

COMPUTATION OF GUST-CASCADE INTERACTION USING THE CE/SE METHOD

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The problem 2 in Category 3 of the 4th Computational Aeroacoustic(CAA) Workshop [1] is solved using the space-time conservation element and solution element (CE/SE) method [2]. This problem models rotor-stator interaction in a 2D cascade. It involves complex geometries and flow physics including vortex shedding and acoustic radiation. The parallel version of the 2D nonlinear Euler solver is used with an unstructured triangular mesh to solve this problem. The Giles approach [3] is incorporated with the CE/SE method to handle non-equal pitches of the rotor and stator. Validation on the Giles approach is performed using Problem 3.1 in the 2nd CAA Workshop.

The space-time CE/SE method is a finite volume method with second-order accuracy in both space and time. The flux conservation is enforced in both space and time instead of space only. It has low numerical dissipation and dispersion errors. It uses simple non-reflecting boundary conditions and is compatible with unstructured meshes. It is simple, flexible, and generate reasonably accurate solutions. The CE/SE method has been successfully applied to solve numerous practical problems, especially aeroacoustic problems [4].

Some preliminary numerical results of the benchmark problem 3.2 of the 4th CAA Workshop are shown in Figs. 1-5. The steady-state pressure contour is plotted in Fig. 1. The mean pressure distribution on the blade surface is compared with Turbo solution in Fig. 2, showing a good agreement. The sound pressure level versus the rotor harmonic n at the six designated positions on the blade surface, three locations at inlet plane, and three locations at the outlet plane are plotted in Figs. 3 and 4, respectively. It can be seen that the acoustic response exists only at the excitation frequencies ($n = 1, 2, 3$). On the blade surface, the acoustic wave at $n = 1$ is dominant, while at the inlet and outlet planes, the sound pressure level at $n = 2$ becomes the largest, which is similar to the results presented in [5]. In Fig. 5, the distribution of sound pressure level at different spatial modes along the x - direction is plotted for $n = 1, 2, 3$, respectively. It shows that the spatial modes $m = -32$ and 22 at $n = 1$ exponentially decay, and the spatial modes $m = 10$ at $n = 2$, $m = -42$ and 12 at $n = 3$ propagate both upstream and downstream, which agrees with the prediction based on the linearized theory [6]. Some oscillations are observed in Fig. 5(c), which needs to be investigated further. In the final paper, the numerical results will be compared with a frequency-domain solver LINFLUX solution if it is available.

References

- [1] The Proceeding of the Fourth Computational Aeroacoustics (CAA) Workshop on Benchmark Problems, to appear as a NASA/CP.
- [2] S.C. Chang, "The Method of Space-Time Conservation Element and Solution Element – A New Approach for Solving the Navier-Stokes and Euler Equations," *J. Comput. Phys.*, **119**, pp. 295-324, (1995).
- [3] M. B. Giles, "Generalized Conservation Cells for Finite Volume Calculations," AIAA-87-1118, July, 1987.
- [4] X.Y. Wang, S.C. Chang, A. Himansu, and P. Jorgenson, "Gust Acoustic Response of a Single Airfoil Using the Space-time Method," AIAA 2002-0801, Reno, NV, January, 2002.
- [5] S. Sawyer, M. Nallasamy, R. Hixon, R.W. Dyson, L.D. Koch, "Computational Aeroacoustic Prediction of Discrete-Frequency Noise Generated by a Rotor-Stator Interaction," AIAA-2003-3268, May 12-14, 2003.
- [6] S.N. Smith, "Discrete Frequency Sound Generation in Axial Flow Turbomachines," Aeronautical Research Council Reports and Memorandum, No. 3709, 1973.

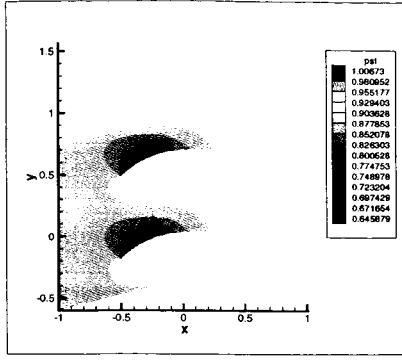


Figure 1: Numerical solution of the mean pressure contours.

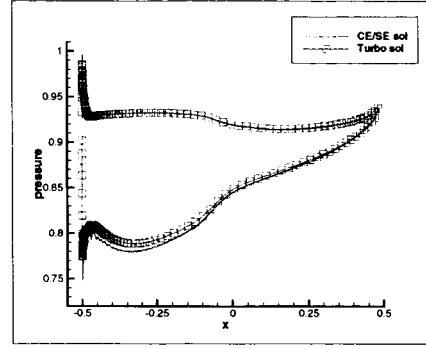
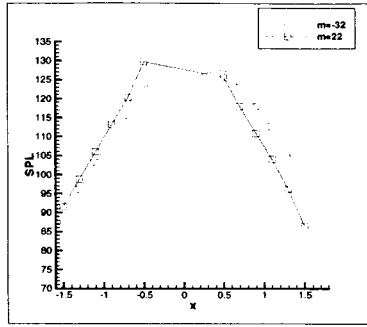
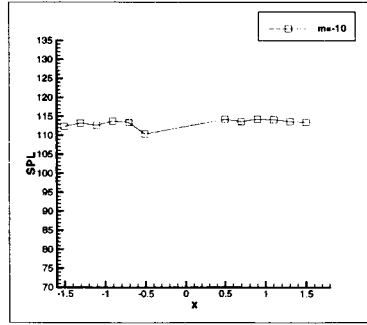


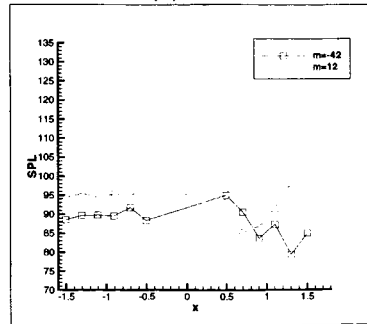
Figure 2: Mean pressure distribution on the blade surface compared with Turbo solution.



(a) $n=1$



(b) $n=2$



(c) $n=3$

Figure 5: The distribution of sound pressure level along the cascade for different spatial modes (m) at $n = 1, 2, 3$.

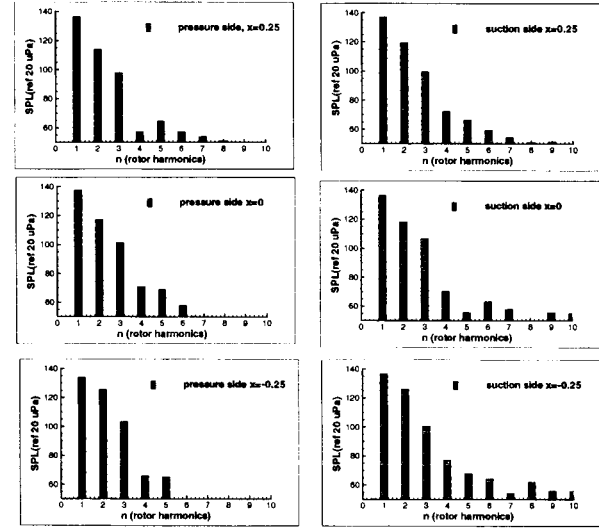


Figure 3: Sound pressure level at six different locations on the blade surface at $n = 1, 2, 3$.

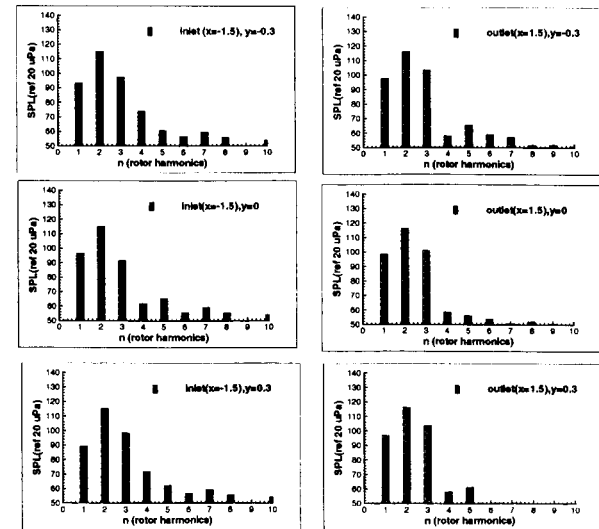


Figure 4: Sound pressure level at three different locations at inlet/outlet planes at $n = 1, 2, 3$.